

Description

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METHOD AND DEVICE FOR TRANSFERRING DATA WHEREIN A BIT RATE
ADAPTATION MODEL IS SIGNED BETWEEN THE TRANSMITTER AND THE
5 RECEIVER

10 The invention relates to a method and a correspondingly designed
device for transferring data according to an ARQ method, especially
a hybrid ARQ method, in a communication system, especially a mobile
radio system.

15 The use of so-called packet-access methods or packet-oriented data
connections is often recommended especially in connection with
mobile radio systems, since the message types produced often have a
very high burst factor with the result that only short periods of
activity exist, interrupted by long breaks. Packet-oriented data
connections may in this case considerably increase efficiency
compared to other data transfer methods in which a continuous data
stream is present, since, in data transfer methods with a continuous
20 data stream, once a resource has been allocated, such as - for
example - a carrier frequency or a time slot, it remains allocated
during the entire communication relationship, i.e. a resource
remains occupied even if there are momentarily no data transfers
taking place, which means that this resource is not available for
25 other network users. The result is that the narrow frequency range
available for mobile radio systems is not used to best effect.

30 Future mobile radio systems, such as - for example - those that
comply with the mobile radio standard UMTS (Universal Mobile
Telecommunications System), will offer a multitude of different
services whereby multimedia applications will become increasingly
prevalent alongside pure voice transmission. The diversity of
services associated with this, with different transmission rates,

requires a highly flexible access protocol on the air interface of future mobile radio systems. Packet-oriented data transmission systems have proved to be highly suitable in this context.

5 In connection with UMTS mobile radio systems, a so-called ARQ (Automatic Repeat Request) method has been proposed in packet-oriented data connections. In this method the data packets transferred from a transmitter to a receiver are checked for quality at the receiving end following decoding. If a data packet is errored
10 on receipt, the receiver requests retransmission of this data packet by the transmitter, i.e. a repeat data packet which is identical or partially identical to the one previously sent and which was errored on receipt, is sent from the transmitter to the receiver (the terms full or partial repeat are used to indicate whether the quantity of
15 data contained in the repeat data packet is less than or equal to that of the original data packet). With regard to this ARQ method proposed for the UMTS mobile radio standard, which is also known as a hybrid ARQ method, the intention is for both data and so-called header information to be transmitted in a data packet, whereby the
20 header information also contains information for error checking, e.g. CRC (Cyclic Redundancy Check) bits, and can also be coded for error correction (known as FEC, Forward Error Correction).

In accordance with the current status of UMTS standardization, it is
25 proposed that the bits in the individual data packets and/or repeat data packets be transferred following execution of a corresponding channel coding by means of QAM modulation (quadrature amplitude modulation). In this procedure the individual bits are mapped, via a process known as "gray mapping", onto corresponding QAM symbols

which form a two-dimensional symbol area. This is problematic, since, in the proposed QAM modulation with alphabetic scope, which includes more than four QAM symbols, the reliability of the bits to be transferred varies considerably between the higher-value bits and the lower value bits. This is particularly disadvantageous with regard to the channel coding that is to be carried out, since - for this purpose - it is preferable to use turbocoders which require the reliability of the bits to remain consistent in order to achieve a sufficiently high level of efficiency. In a hybrid ARQ method, in which the repeat data packet is identical to the original data packet, the result of the aforementioned feature of variable bit reliability is that certain bits of the data packet and repeat data packet are to be found at the same place in the QAM symbol area, thus reducing the efficiency of the entire data transfer and limiting the data throughput at an early stage.

In order to resolve this problem it has already been proposed that those bits which occur in the same place in the original data packet and in the repeat data packets be mapped to different QAM symbols in the QAM symbol area by dynamic rearrangement of the "gray mapping".

This will be explained in greater detail below with reference to Figs 4A-4D. Fig. 4A shows the signal constellation/QAM symbol area for a 16-QAM modulation, in which bits i_1 and i_2 as well as q_1 and q_2 are mapped to a corresponding QAM symbol 26 of the two-dimensional QAM symbol area 25 in the sequence $i_1 q_1 i_2 q_2$. Each of the columns/rows of QAM symbol 26 in the two-dimensional QAM symbol area

25 that can be used for each bit i_1 , i_2 , q_1 , q_2 is marked with a line. Thus - for example - the bit $i_1 = "1"$ can only be mapped onto QAM symbols in the first two columns of the QAM symbol area. Thanks to "gray mapping" the reliability of the higher-value bit i_1 is greater
5 than the reliability of the lower value bit i_2 . In addition, the bit reliability of the bit i_2 fluctuates depending on the corresponding QAM symbol 26 transferred (i.e. depending on whether the corresponding QAM symbol 26 is arranged in the outer left or outer right column of the QAM symbol area 25). The same applies for bits q_1
10 and q_2 , since bits q_1 and q_2 are mapped in a manner equivalent to the mapping of bits i_1 and i_2 (albeit orthogonally for this purpose).

According to the conventional methods explained on the basis of Figs 4A-4D, it is proposed that a different "gray mapping" be used for
15 repeat data packets than the one used for the original data packets. Thus - for example - the "gray mapping" illustrated in Fig. 4B can be used for a first repeat data packet, whilst a "gray mapping" as shown in Fig. 4C is used for a second repeat data packet, and a "gray mapping" as shown in Fig. 4D can be used for a third repeat
20 data packet. Comparison of Figs 4A-4D clearly shows that different QAM symbols 26, i.e. different points in the two-dimensional QAM symbol area 25, are mapped to one and the same bit combination i_1 q_1 i_2 q_2 . This dynamic variation of the "gray mapping" may, for example, continue to the extent that, after a certain number of repeats, each
25 bit i_1 , i_2 , q_1 and q_2 is transferred to a place in the QAM symbol area 25 with excellent or good reliability or poor reliability, whereby this procedure can be optimized for a different number of repeats.

It may be seen from Fig. 4A-4D that this procedure is relatively costly since the "gray mapping" process must be modified for each repeat data packet.

5 The object of this invention is therefore to propose a method and a correspondingly designed device for transferring data according to an ARQ method, in which the problem explained above - i.e. that of achieving reliable data transfer with high data throughput - may be resolved by simple means.

10 This object is achieved by the features in the independent claims. The subclaims define in each case preferred and advantageous embodiments of this invention. The invention also includes transmission and receiving devices that are designed for
15 implementing the methods defined with the method claims.

The invention is thus based on the concept of signaling and/or transferring the bit rate adaptation model to be used for bit rate adaptation, in particular the parameters required for calculating
20 this bit rate adaptation model, between the transmitter and receiver, in order to retrieve the transferred information with good quality at the receiving end.

Depending on the embodiment of the invention, the signaling of the
25 bit rate adaptation model or the transfer of the parameters required in order to calculate this bit rate adaptation model is carried out from the transmitter to the receiver or vice versa.

In particular, one bit may be provided for this signaling of the bit
30 rate adaptation model, and this bit - for example - may be transferred with the corresponding data packet or as part of the

corresponding data packet, and indicates whether the data packet is a self-decoding or a non-self-decoding data packet depending on whether this bit is occupied by a "1" or a "0", for example.

5 Assuming an optimum channel is used, self-decoding data packets contain so many systematic bits that the data packet can be decoded at the receiving end solely on the basis of the bits in the said data packet. In particular, a self-decoding data packet may contain all systematic bits.

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The invention is also based on the finding that, if bits are repeated (at least some of the bits in the data packet are transferred within the data packet more than once), all systematic bits are always transferred and therefore the data packet is always self-decoding. Thus in this case any signaling as to whether the data packet is self-decoding or non-self-decoding is superfluous and the transmission resource provided for this purpose, such as - for example - the aforementioned bit, may be used for other purposes. In particular, this transmission resource may be used for signaling of bit rate adaptation models to be used for bit rate adaptation, especially for transferring the parameters required for calculating these bit rate adaptation models. As a result it may be possible, where bits are repeated, to signal a greater number of different rate adaptation models for self-decoding data packets than if bits are punctured.

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In general the invention enables data transfer according to an ARQ process to become more flexible and the transfer resources available to be used more effectively.

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A development of the invention is based on the concept of applying different rate adaptation models, i.e. different puncturing or

repetition models, to the individual bits of the original data packet and of the individual repeat data packets, so that bits with an identical information source, in particular all bits with an identical information source, are transferred from the transmitter to the receiver after bit rate adaptation has been carried out in different places in the data packet and in the repeat data packet.

As a result the corresponding bits come to be located at different places in each data packet even before the QAM modulation is carried out, and are thus mapped to different points or QAM symbols in the QAM symbol area without modification of the "gray mapping".

Moving the rate adaptation model between the originally transmitted data packet on the one hand to the subsequent repeat data packet or packets on the other, means that one and the same code rate is obtained; it also means, however, that the transmission quality and the bit error rate can be improved.

In this way an even distribution of reliability in the bits to be transferred between the data packet and the subsequent repeat data packets is achieved, so that an efficient channel coding procedure, for example using turbo-coders, can be carried out, the overall result being that a sufficiently high level of efficiency in information or data transfer is achieved whilst at the same time a high data throughput is guaranteed.

If several repeat data packets are requested it is advantageous to use whichever rate adaptation model was applied - i.e. the appropriate puncturing/repetition model is applied, being moved from

repeat data packet to repeat data packet.

In a further embodiment, a rate adaptation algorithm known per se is provided for the purpose of bit rate adaptation, whereby an offset
5 value used according to this rate adaptation algorithm, and which essentially determines the rate adaptation model to be used in each case, varies between the original data packet and the repeat data packet or between the individual repeat data packets. The variation of this offset value may enable a more efficient coding to be
10 achieved than in a conventional hybrid ARQ method.

The channel-coded bit stream may preferably be separated into several parallel partial bit streams (in a process known as bit separation) for this purpose, whereby rate adaptation models that
15 are independent of one another, i.e. with independent puncturing or repetition of bits, are applied to the individual partial bit streams, so that, once the corresponding bits of this partial bit stream have finally been combined (in a process known as bit collection), the required bit rate adaptation can be achieved, with
20 the different offset value, with regard to the original data packet and the individual repeat data packets. The separation of the bit stream into several parallel partial bit streams enables a particularly high degree of flexibility to be achieved in channel coding.

25 Since the corresponding receiver of the data packets or repeat data packets thus processed ought to know which offset value was used, and since any explicit transfer of this offset value may be disadvantageous, the offset value may - for example - be modified
30 synchronously with the corresponding time slot and/or with the

corresponding frame, so that the receiver may infer the offset value used in each case directly from the time slot and/or frame received. In a different embodiment of the invention, this offset value is to be signaled between the transmitter and the receiver.

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In the bit separation process explained above, involving the separation of the bits into several parallel partial bit streams, in the final bit collection the different parallel partial bit streams may also be combined with one another proportionately for each data packet or repeat data packet, whereby this process may be used to particularly advantageous effect if bit repetition is applied. The offset value explained above may be adjusted for the original data packet and the individual repeat data packets such that the moving together of the resulting rate adaptation models is maximized and/or as many as possible of the matching bits in the original data packet or the corresponding repeat data packet are mapped onto different points in the two-dimensional symbol area during the final modulation.

20 The method described above functions optimally if the bits are mapped onto the required modulation symbol area immediately after rate adaptation has been carried out. However, this is not always the case since a process called interleaving - whereby the bits are chronologically rearranged - often takes place between rate adaptation and modulation. In a random interleaver, neighboring bits would be distributed randomly to the corresponding points or symbols in the two-dimensional symbol area, so that movement by one bit - which can be achieved by varying the offset value as described above - would also result in a random modification of the points or symbols of the two-dimensional symbol area. However, this would not

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be ideal since it is best for the allocation to be modified such that a bit that is less reliable during transmission of the original data packet is mapped, in a repeat data packet to be transferred subsequently, to a position with higher reliability in the modulation symbol area (e.g. the QAM symbol area) and vice versa, whilst in a random rearrangement, only approximately 50% of the maximum potential gain might be achieved.

For this reason it is preferable for a highly regular interleaver, for example a block interleaver, to be used for interleaving, whereby - in addition - the number of columns to which the interleaver distributes the bits, with subsequent column rearrangement or column permutation, and the number of points or symbols of the symbol area used that are differently weighted or have different levels of reliability, should be coprime, so that optimum mapping is achieved.

This variation of the invention is considerably far less complex compared to the method explained at the start and known from the prior art.

This invention is explained in greater detail below with reference to the attached drawing on the basis of preferred embodiments of packet-oriented data transfer in a mobile radio system, whereby the invention is of course not limited to mobile radio systems, but can be used generally in any type of communication system in which an ARQ method is provided for data transfer.

Fig. 1 is a diagram for clarifying signal processing, in particular according to a packet-oriented ARQ method of this invention,

Fig. 2 is a diagram for clarifying the communication in a mobile radio system,

Fig. 3 shows a rate adaptation algorithm, which - for example - may be used in this invention for the purpose of rate adaptation, and

Figs. 4A-4D are diagrams for clarifying the mapping of bits from an originally transmitted data packet or from corresponding repeat data packets, to QAM symbols, according to the prior art.

As already explained, the following is based on the idea that packet-oriented data transfer in a mobile radio system, as shown schematically in Fig. 2 by way of example, is to be implemented with the help of this invention. Thus Fig. 2 shows by way of example the communication between a base station 1 and a mobile station 2 of a mobile radio system, for example a UMTS mobile radio system. The transfer of information from the base station 1 to the mobile station 2 takes place via the so-called downlink channel DL, whilst the transfer of information from the mobile station 2 to the base station 1 takes place via the so-called uplink channel UL.

This invention is explained below using as an example a packet-oriented data transfer from the base station 1 to the mobile station 2, i.e. a packet-oriented data transfer via the downlink channel, in which the invention can however also be used similarly on data transfer via the uplink channel. This invention is further explained below on the basis of the signal processing measures to be executed in the transmitter concerned, whereby however it is important to note that a corresponding signal processing operation in the reverse

sequence is required in the relevant receiver for evaluation of the data processed in this way at the transmitter end, which means that this invention affects not only the transmitter end but also the receiver end.

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Fig. 1 shows the signal processing of the data and header information to be transferred in data packets following a hybrid ARQ method according to the invention.

10 On the header side the header information created by a function block 3 is supplied to a function block 12, which ensures that all headers of all data packets that are to be transmitted in one and the same radio packet are linked together into a single header (in a process known as header concatenation). A function block 13 inserts
15 CRC bits for header detection into the resulting header information. The resulting bit stream is then subjected to channel coding by a function block 14 and rate adaptation by a function block 15. An interleaver, 16, causes the symbols and/or bits supplied to it to be arranged in a particular way and time-interleaved. The data blocks
20 produced by the interleaver 16 are allocated by a function block 17 to the individual transmit or radio frames (known as radio frame segmentation).

A function block 4 is also provided on the data side for the
25 insertion of CRC bits. A function block 5 is used for splitting the data supplied to a channel coder 6 such that a coding process limited to a specific number of bits can always be carried out by the channel coder 6.

30 Because of the channel coding carried out by the channel coder 6, the actual data to be transmitted has redundant information inserted

in it. Systematic bits and parity bits are systematically produced by the channel coder, whereby each systematic bit is identical to an information bit and parity bits are redundant bits that are determined from the information bits. In an ARQ method,

5 consecutively transmitted data packets contain bits with the same information source, i.e. bits that each depend on the same information bit.

The bits produced by the channel coder 6 are supplied to a function
10 block 19, which adjusts the bit rate of the bit stream by masking or omitting individual bits (known as puncturing) or repeating individual bits. So-called DTX (Discontinuous Transmission) bits can be inserted into the data stream by a subsequent function block 9. Also provided on the data side are function blocks 10 and 11, which
15 perform the same functions as do function blocks 16 and 17 on the header side.

Finally the bits produced on the data and header side are mapped or multiplexed by a function block 18 on whatever physical transfer or
20 transmission channel is available at the time and transferred to the receiver with the help of a suitable modulation procedure, for example QAM modulation.

In the hybrid ARQ method, if a data packet is incorrectly received
25 or decoded by the receiver, a repeat data packet is requested. The repeat data packet is identical or partially identical to the previously sent and incorrectly received packet (HARQ type I, Chase Combining). The latter methods are known as partial incremental

redundancy (IR) or as HARQ type III. As a further option the repeat packets may also consist purely of additional redundant information known as parity bits (full IR or HARQ type II).

- 5 The terms full or partial repeat are used to indicate whether the quantity of data contained in the repeat data packet is less than or equal to that of the original data packet. The data packet and the corresponding repeat data packet have at least some bits with the same information source. Therefore, by evaluating the data packet
10 originally sent together with the subsequent repeat data packets requested, the receiver can retrieve the originally transmitted information with better quality.

- The function section 19 includes a function block 20, which -
15 dependent upon control exercised by the function block 3 - separates the coded bits produced by the upstream channel coder 6 into at least two parallel partial bit streams, which are each subjected to rate adaptation separately, i.e. independently of one another. In this regard Fig. 1 shows three partial bit streams A-C, each of
20 which has one function block 21-23 provided for rate adaptation as appropriate, i.e. for puncturing or repetition of individual bits. This results in several differently coded parallel partial bit streams, which are supplied to a further function block 24. This further function block 24 has the task of bit collection, i.e.
25 collecting the individual bits from the parallel bit streams in the same sequence that was used by function block 20 for the bit separation process, i.e. the separation into the individual parallel partial bit streams. This is to ensure that the sequence of bits

remaining after rate adaptation remains unchanged overall.

As already explained, the rate adaptation processes provided for the individual partial bit streams A-C by function blocks 21-23 may take place completely independently of one another. In particular, it is also possible for the bits from one or more bit streams not to be subjected to any puncturing or repetition at all. In general the rate adaptation process for the individual parallel partial bit streams A-C should be selected such that a required rate adaptation model is applied by the entire function section 19 to the channel-coded bit stream produced by function block 6 for each data packet or repeat data packet. By implementing function section 19 with several rate adaptations in parallel as shown in Fig. 1, extremely high flexibility can be achieved in the coding process.

The function section 19 is designed such that, according to the control exercised by the function block 3, it applies a different rate adaptation model to the bits of a repeat data packet than to the bits in the corresponding, originally transmitted, data packet. This means that function section 19 is notified by function block 3 as to whether a repeat data packet has been requested by the corresponding receiver, whereby function section 19 in this case selects and/or adjusts the rate adaptation model implemented by the individual function blocks 21-23, such that the bits of the repeat data packet are processed overall with a different rate adaptation model than the bits of the basic data packet that was originally transmitted.

The rate adaptation process implemented overall by the function section 19 may - for example - be carried out according to the rate

adjustment algorithm shown in Fig. 3, which is already known per se from the prior art.

The rate matching (i.e. rate adaptation) algorithm contained in the UMTS standard is described in [25.212]. It uses the following as the main parameters:

- X_b : number of coded bits per packet in bit stream b
- e_{ini} : starting error value ($N_{TTI} / 3$)
- 10 • e_{plus} : increment in the error value during puncturing/repetition
- e_{minus} : decrement in the error value per output bit.

In the existing standard, e.g. for the downlink of turbocoded transport channels with fixed bit position (Chapter 4.2.7.2.1 in [25.212]), these parameters are to be calculated as follows in cases of puncturing:

$$e_{ini} = N_{max} . \quad (5. 1)$$

where N_{max} refers to the maximum number of bits per parity bit stream via all transport formats and transport channels, calculated before rate adaptation. The increments and decrements in the error values are calculated as follows:

$$e_{plus} = a \times N_{max} , \quad e_{minus} = a \times |\Delta N_i^b| , \quad (5. 2) ,$$

where $a = 2$ for the first parity bit stream and $a = 1$ for the second parity bit stream. $|\Delta N_i^b|$ is the number of punctured bits per bit stream b for the transport channel i .

In particular, a rate adaptation parameter e_{ini} is used which indicates an offset value with regard to the rate adaptation model used for each rate adaptation carried out. An error variable e is initialized with this offset value e_{ini} at the beginning of the rate adaptation algorithm shown in Fig. 3, whereby the error e indicates

for example the ratio between the current puncturing rate and the required puncturing rate in the case of puncturing.

Finally the index m of the bits currently to be processed is set to the first bit, i.e. to the value 1, and an auxiliary error parameter e_{plus} is initialized.

A loop is then run for all bits in the data packet No. i to be processed, whereby the number of bits for the data packet in question is indicated by X_i .

Within this loop, first the error e is repeated and checked using a further auxiliary error parameter e_{minus} , to ascertain whether the resulting error e is greater than zero, in order thus to determine whether or not the corresponding bit is to be punctured. If the above condition is fulfilled, the corresponding bit is set to an auxiliary value δ and is thus punctured, i.e. blocked for the subsequent data transfer.

If, however, the above condition is not fulfilled, the corresponding bit is selected for the data transfer and the error e is calculated again using the first auxiliary error parameter mentioned above, namely e_{plus} .

To conclude the rate adaptation algorithm or puncturing algorithm, the bit index m is incremented and thus the next bit is selected for processing as explained above.

The rate adaptation model applied to the bits in a data packet or repeat data packet can essentially be affected by appropriate selection of the offset value e_{ini} . By varying this offset value e_{ini} it is possible for a different rate adaptation model to be applied to a repeat data packet than was applied to the corresponding,

originally transmitted, data packet, whereby the rate adaptation may be applied in particular with reference to the parity bits of the individual partial bit streams A-C (compare Fig. 1).

- 5 The offset value e_{ini} is advantageously selected for the originally transmitted data packet and the repeat data packet, such that the moving together of the resulting rate adaptation models is maximized. Furthermore the offset value e_{ini} for the originally transmitted data packet and the repeat data packet is to be
- 10 advantageously selected such that - during the final modulation, in particular the QAM modulation - as many as possible of the matching bits in the two packets are mapped onto different points, i.e. different QAM symbols, of the corresponding two-dimensional QAM symbol area (compare in this regard the mappings shown in Fig. 4,
- 15 for example).

A self-decoding data packet is normally used for the first transfer, i.e. all systematic bits are transferred, for example. If, once these systematic bits are subtracted, there is only sufficient space

20 remaining in the transfer for some of the parity bits, the parity bits are punctured accordingly (i.e. not transferred). However, if the available space is greater than all existing parity bits, then systematic bits and parity bits are repeated with the same rate. The selection of punctured/repeated bits takes place in UMTS by means of

25 an algorithm which distributes these punctured/repeated bits as evenly as possible within the coded data block.

In a repeat data transfer the rate adaptation model - and thus the bits to be transferred in each case - are selected on the basis of a

30 specific number of signaling bits, such that, firstly, different

HARQ types are implemented, and, secondly, the bits transferred in each transfer are as different as possible, in order to achieve a decoding gain and/or even distribution of the total energy to all bits. A specific rate adjustment model or the parameters for
5 calculating a specific rate adaptation model here correspond to a specific redundancy version. A variant of this invention shows how the selection of redundancy versions can be optimized for a given number of bits for signaling of the various redundancy versions, both in the case of puncturing and also - in particular - in the
10 case of repetition.

To enable the receiver to interpret the received data packet correctly, a signal is sent between the transmitter and the receiver to indicate whether the data packet is a self-decoding or a non-
15 self-decoding data packet. Bit signaling information is required for this purpose. Within either type (self-decoding or a non-self-decoding), further redundancy versions can then be defined which can likewise be explicitly signaled. If n bits are available for signaling, then the total amount of information to be signaled
20 consists of one bit for differentiating between self-decoding and non-self-decoding, and $n-1$ bits for describing a specific redundancy version from a multitude of redundancy versions.

Use of signaling bits

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Self-decoding data packet	1 bit
Redundancy version	$n - 1$ bits

However, differentiation between self-decoding and non-self-decoding data packets is worthwhile only in the case of puncturing, in which not all coded bits can be transferred. In the case of repetition,

self-decoding exists a priori since all coded bits can indeed be transferred several or even many times over. In the case of repetition, therefore, it is advantageous to use all n bits in order to differentiate between different redundancy versions. Particularly
5 in the case of repetition, even where n is a small number, this makes it possible to ensure, with far greater certainty, that the power is distributed as evenly as possible over all transferred bits after a repeat data packet is transferred and the first data packet is overlaid with the repeat data packet at the receiving end. An
10 exemplary embodiment of the use of the signaling bits according to the invention is shown in the following table:

Use of signaling bits in puncturing and repetition

	Puncturing	Repetition
Self-decoding data packet	1 bit	0 bits
Redundancy version	$n - 1$ bits	n bits

15 For example, the value $n=3$ might be selected here. This permits a reasonable number of different redundancy versions and, furthermore, does not require an unnecessarily high number of signaling bits.

20 The method presented here optimizes the signaling process since the significance of the signaling bits depends on whether bits are repeated or punctured in the transfer in question. If a total of N_g signaling words is provided (i.e. $N_g = 2^n$ where n bits are provided for signaling), then the N_g signaling words are distributed as
25 follows.

In the case of puncturing the signaling words are divided into two partial quantities, one for transfers of the self-decoding type

(i.e. systematic bits are included), and a second for transfers of the non-self-decoding type (systematic bits are not usually included, in particular systematic bits are not included). Within these partial quantities, then, different signaling words
5 differentiate between different redundancy versions.

Ns redundancy versions of the self-decoding type (Partial Incremental Redundancy) are selected, which indicate self-decoding redundancy versions, and Ng - Ns redundancy versions of the non-
10 self-decoding type (Full Incremental Redundancy) are provided. If $N_s = N_g/2$, the coding already provided is used. Another extreme case is $N_s = 1$. In this case only a single self-decoding redundancy version is provided (which is provided for the initial transfer) and Ng-1
15 non-self-decoding redundancy versions. This is the best choice where Ng is relatively small (maximum 8), since it still enables a relatively high number of redundancy versions with full IR to be defined.

In the case of repetition, no partial quantities are formed and all
20 signaling words are used to differentiate between various redundancy versions.

The main innovations in this exemplary embodiment are the differentiation of cases of repetition and puncturing for the
25 significance of the signaling bits and the optimization of the number of possible HARQ types and different redundancy versions, and - in the case of repetition as well as for puncturing - with a specified number of signaling bits.

30 Different redundancy versions may be generated according to a parameter variation of the parameter e_{ini} , but may also be generated

according to any other procedure.

Until now, only such parameters have been described as influence the rate adaptation or the bit selection for an HARQ system, and the way in which such parameters can be signaled. In fact, it is by varying other parameters that improvements in the transfer rate are achieved. An example of such a parameter is the variation in the mapping of bits to 16 QAM symbols in the stage for mapping modulation symbols. The principle of this method is described in the following standardization document, by way of example:

R1-01-0237, Panasonic, "Enhanced HARQ Method with Signal Constellation Rearrangement, "3GPP TSG RAN WG1, Las Vegas, USA, February 27th-March 2nd 2001;

R1-01-1059, Panasonic, "Comparison of HARQ Schemes for 16-QAM, "3GPP TSG RAN WG1, Sophia Antipolis, France, November 5th-7th 2001;

R1-01-0151, Panasonic, "16-QAM HARQ Bitmapping Scheme", Espoo, Finland, January, 2002.

This method essentially achieves good results if the same redundancy version is used in repetition (chase combining) or if the redundancy versions differ only slightly in terms of their bit content. In contrast, incremental redundancy achieves the best results if the individual redundancy versions transmitted differ greatly. Ideally, therefore, the signaling should be designed such that different redundancy versions as well as different mapping variants are used for bitmapping to 16 QAM symbols. However, this is not always possible because of the limited availability of signaling bits. In this case it is necessary to decide whether the signaling bits are

used for selecting redundancy versions or selecting mapping variants. Embodiments for these exemplary variants are explained below. In an initial exemplary embodiment with reference to this aspect, no mapping variants - but exclusively redundancy versions -
5 are signaled if the modulation type used is not 16 QAM or 8PSK, or a higher-value modulation, but only BPSK, QPSK, or a different modulation type which does not have different values for modulation symbols.

10 In a further exemplary embodiment, for example if a 16QAM modulation is used, it is preferable for mapping variants to be signaled - if necessary at the expense of redundancy versions - if so many bits are available for transfer that all the bits present can be transferred, in other words if puncturing does not need to be used
15 for rate adaptation.

In a further exemplary embodiment, it is preferable for mapping variants to be signaled (if necessary at the expense of redundancy versions), if fewer bits are available for transfer, so that not all
20 the bits present can be transferred, in other words puncturing must be used for rate adaptation if the puncturing rate, i.e. the proportion of bits to be punctured, does not exceed a certain predefined value. In principle this predefined value may be selected at random, but it is better if it is not lower than 50%, since, with
25 50% puncturing by selection of two completely orthogonal (i.e. disjunct) redundancy versions, an excellent improvement can be achieved through incremental redundancy. Otherwise it is not possible, in this case, to achieve any additional gain through mapping variations, since the two transfers do not contain any
30 common bits in which a gain might be produced. In this case,

therefore, it is not absolutely necessary to signal mapping variations in addition to redundancy versions.

In a further exemplary embodiment, the aforementioned exemplary
5 embodiments may be expanded such that there is no firm switching to
and fro between signaling formats depending on the parameters
described above, but that more or fewer redundancy versions or
mapping variants are signaled according to parameter. There follows
an example of a case in which a total of four alternatives might be
10 signaled:

- If the puncturing rate is more than 50%, all four alternatives are
used for the signaling of redundancy versions and no mapping
variants are signaled.
- If the puncturing rate is between 50% and 33%, 3 alternatives are
15 used for the signaling of redundancy versions and one alternative
is signaled for a mapping variant (which can then only be used for
a special redundancy version).
- If the puncturing rate is between 33% and 20%, two alternatives
(i.e. one bit) are used for the signaling of redundancy versions
20 and likewise two alternatives (i.e. one bit) are signaled for two
mapping variants. This enables the redundancy version and mapping
variant to be selected independently of one another.
- If the puncturing rate is between 20% and 10%, an alternative is
used for signaling a redundancy version (which can then only be
25 used for a special mapping version), and three alternatives are
used for mapping variants.
- If the puncturing rate is less than 10% with repetition up to 33%,
all four alternatives are used for the signaling of mapping

variants and no redundancy versions are signaled.

- If the repetition rate is over 33%, then two alternatives (i.e. one bit) are again used in each case for the signaling of redundancy versions and mapping variants. This enables the redundancy version and mapping variant to be selected independently of one another.

In the above exemplary embodiments the ratio of bits available for transfer to bits present, and the resulting puncturing or repetition rate, has been used as a criterion. It is necessary to point out that, even though this puncturing rate may well be the puncturing rate that results from the ratio of number of bits after channel coding to number of bits that are transferred, there may be cases in which further interim stages are carried out. For example, puncturing may be carried out first on an interim number of bits that corresponds to the size of a receiving memory, and it is only from this number that puncturing or repetition is carried out on the number of bits to be transferred. In this case the criterion would preferably be the puncturing rate/repetition rate in this second stage, not the overall rate.

According to one exemplary variant of the invention, an interleaver is used for the function block 10 shown in Fig. 1, which does not interleave randomly but in a highly regular manner. A block interleaver, for example, might be used for function block 10. If the interleaver used as function block 10 is a highly regular interleaver, and if the number of columns to which the interleaver distributes the bits supplied to it and the number of differently weighted points in the two-dimensional QAM symbol area or the number

of differently weighted modulation points in general, are coprime, the result is optimum mapping. According to the current state of UMTS standardization, the proposed interleaver is a block interleaver with additional column replacement, which distributes
5 neighboring bits to columns separated from one another in multiples of "5", and then exchanges the columns. For example, if 30 columns are used the column permutation is as follows: column no. 0, 20, 10, 5, 15, 25, 3, 13, 23, 8, etc. Since the value "5" is coprime with the number of different bits, for example in a 16-QAM modulation
10 (i.e. two bits) and a 64-QAM modulation (i.e. three bits), then this combination, for example, results in good scrambling or mapping to the corresponding modulation points.

This method as described above is possible for both puncturing and
15 repetition, as well as for the most diverse transport formats. By appropriately selecting the parameters (e.g. number of redundancy versions, number of bit streams), it can be adapted to different modulation and coding schemes.

20 References [25.212] "Multiplexing and Channel Coding (FDD) Release 1999)," Technical Specification 3GPP TS 25.212